

## **Specifications for a Precision CNC Vertical Machining Center**

### **Introduction**

The Naval Research Laboratory Vacuum Electronics Branch requires a high precision computer numerically controlled (CNC) vertical machining center. The machining center will be used for the fabrication of high precision millimeter-wave vacuum electronic devices, components, and electron beam source electrodes. Essentially, the machining center is a completely automated, computer-controlled milling machine with 3 dimensional cutting capability, characterized by very high absolute positional accuracy, relative repeatability, rigidity, and cutting speed. A wide range of rotary cutting tool types (with automatic tool changing), in conjunction with the three-dimensional programmable relative movement between the cutting tools and mounting table, allows the machining of complex structure shapes and patterns in a wide range of metallic materials that cannot be fabricated using manual milling machines.

The high precision Vertical Machining Center (VMC) must (1) meet or exceed the following “Mechanical Performance Specifications” listed in Section I; (2) must have an integral computer controller, control accessories, and control software that meets, exceeds, or is equivalent to the following “Computer Controller Specifications” listed in Section II; (3) must have physical dimensions and weight that are less than or equal to the “Limits on Machine Dimension and Weight Specifications” in Section III; (4) must have required accessories and tooling that meet or exceed the specifications described in “Required Additional Accessories and Tooling” in Section IV; (5) must be compatible with our utilities as listed in Section V; (6) have a warranty as described in Section VI; (7) must come with a session of onsite training as described in Section VII, and (8) must have documentation as listed in Section VIII.

### **Section I. Mechanical Performance Specifications (must meet or exceed)**

- 1.1 Overall construction of the VMC structural elements shall be from rugged cast-iron, reinforced with ribs to prevent flexing. The VMC shall utilize hardened-steel bearing packs rolling on hardened steel ways on each of the three (X, Y, Z) motion axes.
- 1.2 Motion Ranges for the Axes (when viewed from the front of the machine): 16 inch range for the X-axis (left-to-right motion) ; 12 inch range for the Y-axis (front-to-back motion) ; 10 inch range for the Z-axis (up and down vertical motion).
- 1.3 Spindle Nose to Table Clearance: The combination of the Z-axis vertical motion and the construction of the VMC must allow the distance between the spindle nose and the table to achieve a vertical clearance covering the entire distance range of 4 inches to 14 inches, inclusive.
- 1.4 Table Dimensions And Capacity: The table, which is the X-Y surface onto which materials are mounted for machining operations, must have a total length of 36 inches, with a minimum working surface length of 28 inches. The table must have a width of 12 inches, with a minimum working surface width of 11.5 inches. The table must have a weight capacity of 500 pounds.

- 1.5 Mounting Slots: The table must have at least 3 T-slots, with industry-standard T-slot widths of 0.625 inches (5/8 inches). The slots must be oriented parallel to the X-axis.
- 1.6 Spindle Requirements: The spindle must have a vertically oriented axis, have an industry standard #40 taper, and have a computer-controlled continuously variable range of speeds capable of reaching 15000 RPM (15 thousand revolutions per minute). The spindle must have a brushless vector drive and it must be capable of creating a torque of 17 foot-pounds at 4600 RPM. The energizing motor must be capable of developing 15 horsepower under peak conditions, and 12 horsepower under continuous duty conditions. The energizing motor must be air cooled.
- 1.7 Axis Motion Drives: Each of the three axes (X, Y, and Z) must be driven using double-anchored, pre-tensioned ball lead screws and associated computer-controlled brushless motors, and each axis must be capable of creating 2000 pounds of force, a rapid positioning feed-rate of 1200 inches per minute, and a controllable cutting rate that can reach a peak of 800 inches per minute.
- 1.8 Axis Positioning Accuracy: Each of the three axes (X, Y, and Z) must individually exhibit a positioning accuracy of plus/minus 0.0002 inches (+/- 0.2 thousandths of an inch), and each of the three axes must individually exhibit a repeatability of plus/minus 0.0001 inches (+/- 0.1 thousandths of an inch).
- 1.9 Lubrication System: The VMC must come with an automatic lubrication system installed and capable of lubricating, at a minimum, the ways and ball lead screws of each of the three (X, Y, Z) motion axes, as well as the spindle bearings.
- 1.10 Tool Changer: The VMC must have a built-in automatic tool changer, with a capacity of 10 tools based on industry standard CT40 tool type/taper. The changer must be capable of accommodating tools with weights as large as 12 pounds and diameters reaching 3.5 inches. The average time between tool changes must be faster than 5 seconds, including transit to the changer.
- 1.11 Rigid Tapping: The VMC must be designed and constructed to accommodate rigid tapping, in which the Z axis motion is synchronized with the spindle rotation during the tapping process.
- 1.12 Coolant System: The VMC must have a built-in 3/4 horsepower or greater coolant pump, sump/reservoir, piping, and nozzles to allow coolant (i.e. machining cutting fluid) to be directed towards the material being machined and the cutting tools.
- 1.13 Enclosure: The VMC must have an integral enclosure that surrounds the table, the moving parts associated with the X, Y, and Z axes, the spindle, the work being machined, as well as the entire area beneath these regions, in order to protect the operator from flying metal chips, prevent contact between the operator and moving parts, and to contain and collect the coolant (cutting fluid) that is being pumped onto the material being machined and the cutting tool. The enclosure door must be located at the front of the VMC, and it must have a window to allow viewing of the VMC operation. The enclosure door must have a 22 inch or greater width and a 22 inch or greater height when opened to allow access to the table and spindle. The enclosure and leak-preventing caulking can be either factory-installed or field-installed.

## Section II. Computer Controller Specifications (must meet, exceed, or be equivalent to)

- 2.1 Computer Controller-General: The dedicated computer controller must be capable of controlling all axes (including an auxiliary fourth axis), the spindle, and the tool changer. The controller must be a designed, integral component of the VMC system solely dedicated to CNC operations and control of the internal functions of the VMC, housed in a manner that is sufficiently rugged to withstand machine shop conditions, including the presence of stray metal chips (i.e. attached commercial office or home personal computers are NOT acceptable).
- 2.2 Computer Controller Memory and Accessories: The VMC must come with at least 16 MB factory installed expandable program memory, at least a 20 GB hard disk drive, USB support, a floppy disk drive, and an Ethernet interface for Windows 95, 98, XP, ME, 2000-PRO & Server NT 4.0.
- 2.3 Fourth Axis Control: The VMC control system must have driver interfaces and wiring for controlling a 4th axis brushless-type rotary table.
- 2.4 Computer Control Accessories, Software, and Corresponding Support Hardware: Software to control the machining operations of the VMC, including all axes, the tool changer, and the spindle, must be supplied with the computer controller. In addition to supporting ISO industry standard G-code and M-code, the software and control accessories are to include a Visual Quick Code Programming System for Verticals or equivalent (including OMI, PROMAC, COORD, SO, VQC and QC template files and routines), and associated Probing Software for establishing coordinate references; a tool setting probe; and a work offset probe. Software to allow cutter compensation, graphic program review, coordinate rotation and scaling, high speed machining with look ahead capability, and user definable macros (to create subroutines for custom canned cycles, probing routines, operator prompting, math equations or functions, and family-of-parts machining with variables) is also required. The controller must accommodate 6 spare M-functions. Spindle Orientation software to allow indexing the revolution of the spindle to an operator-selected angle (to within 0.1 degree), using the standard spindle motor and the standard spindle encoder, is required. A home position button, along with the ability to set an additional (2<sup>nd</sup>) home position, is also required.

## III. Limits on Machine Dimension and Weight Specifications (must be less than or equal to)

- 3.1 Maximum Machine Weight: The weight of the VMC, after removal of the shipping crate and prior to any field installed options, must not exceed 4000 pounds. The weight of the VMC after installation of any field-installed options must not exceed 4300 pounds.
- 3.2 Maximum VMC Height During Operation: The maximum height of the VMC during operation must not exceed 98 inches. During on-site assembly procedures or during temporary maintenance operations, the height may not exceed 102 inches.
- 3.3 Requirement to Reduce VMC Height During Rigging. After removal from the shipping crate, but prior to final installation and operation, the height of the VMC needs to be temporarily reduced to 79.5 inches to allow transport and rigging into its final location

through a freight elevator (allowances for rigging equipment height have already been made). The design of the VMC must allow this height reduction to occur at the delivery site by simple, standardized procedures that do not require special tooling or training – and could consist of, for example, temporally disconnecting or repositioning the Z-axis conduit tube and/or associated connections and housings, etc. to the spindle drive, at the onsite location. Any such temporary procedures must not adversely affect the ultimate performance and accuracy of the VMC.

- 3.4 Maximum VMC Width During Rigging: 65 inches maximum, after removal of the shipping crate, when viewed from the front of the machine, but before being readied for operation.
- 3.5 Maximum VMC Width During Operation: 79 inches maximum, when viewed from the front of the machine, prior to the attachment of any field-installed chip removal accessories.
- 3.6 Maximum VMC Depth During Rigging: 82 inches maximum, after removal of the shipping crate, when viewed from the front of the machine, but before being readied for operation.
- 3.7 Maximum VMC Depth During Operation: 90 inches maximum, when viewed from the front of the machine.

#### IV. Required Additional Accessories and Tooling (must include the following items and meet or exceed the specifications )

- 4.1 A chip conveyor, auger style with automatic jam sensing and reversal to clear such jams, is required.
- 4.2 A programmable coolant nozzle capability, suitably located to direct coolant at the point where the spindle tooling is cutting or drilling the work piece and including necessary hardware and control components compatible with the VMC computer controller, is required.
- 4.3 A work light, mounted inside the VMC enclosure, is required.
- 4.4 A set of 24 tooling pull studs, for CT40 tooling, is required.
- 4.5 A cable assembly for M-code / MFIN capability is required.
- 4.6 An early power failure detection module, which will prevent the spindle from dropping in the event of a power failure, is required.
- 4.7 A 160 millimeter (6.3 inch) CNC rotary table with a brushless wrap around motor and 6 standard T-slots, suitable for use as a true CNC 4<sup>th</sup> axis and compatible with the 4<sup>th</sup> axis control interfaces, wiring, and software associated with the main VMC computer controller, is required. A quantity of two complete six inch (top) reversible 3-jaw chucks compatible with the rotary table must also be supplied. A suitable adapter plate for mounting the rotary table to the VMC table, a pneumatic tailstock with a 5 inch center height for use with the rotary table, and a corresponding complete 12 inch by 4 inch tooling block system, a 4.5 inch by 4.5 inch by 12 inch aluminum tombstone, and an A-frame support with 5 inch center, all suitable for use with the rotary table/tailstock assembly, are all required.
- 4.8 A second CNC spindle-type rotary table with a brushless motor, fitted with a A1-6 spindle nose, and suitable for use as a true CNC 4<sup>th</sup> axis and compatible with the 4<sup>th</sup> axis control interfaces, wiring, and software associated with the main VMC computer controller, is also required. A pneumatic draw tube with a 1.75 inch ID through hole, and a compatible 5C collet adapter for use in conjunction with this rotary table are required.
- 4.9 A tool tray for holding collets is required. It can be either stand-alone, or mounted inside or outside the enclosure.

- 4.10 A double-sided rolling tool cart that can be used with various tool holder trays, tool boxes, etc. that are associated with normal operation of the VMC is required.
- 4.11. A tool holder vise compatible with the 40-taper spindle of the VMC is required.

## V. Compatibility with Utilities

- 5.1 The VMC must be compatible with the following existing utilities:

Power: 230 V, 3-phase AC, 60 A per phase, 60 Hz,  
Compressed air: 100-120 psi, 4 CFM

## VI. Warranty

- 6.1 As a minimum, a basic warranty of six months including parts and labor, with an extended warranty of an additional six months including parts and labor, is required.

## VII. Training

- 7.1 Four (4) hours of on-site training, to occur at the time of installation, is required.

## VIII. Documentation.

- 8.1 NRL requires two (2) copies of an operators manual for the complete VMC. This operator's manual must include essential maintenance instructions and maintenance schedules as well as operating instructions.